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# Tornado occurrence in Greece: Influencing variables and spatiotemporal variations

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## Abstract
Tornado occurrence in Greece has been actively recorded for the 5-year period 2010-14. The systematic effort for recording whirlwind activity in Greece, initiated in the year 2000, developed the first Greek tornado database and climatology. This ongoing initiative, in collaboration with technological advancements, has resulted in improved observational and reporting opportunities along with quantitative and qualitative improvement in the database. The objectives of this study are to investigate increased tornado reports over the last 5 years in relation to the previous decade, and examine influencing factors such as; a) population density, b) improvements in recording including the proliferation of observers, c) improvements in observational technology including the use of time-lapse and smart phone cameras, d) reporting possibilities in the internet era and e) public awareness of tornadoes. The 5-year data (2010-14) of tornado, waterspout and funnel cloud occurrences have been analyzed and mapped. Spatio-temporal distributions are highlighted and prone areas identified.

## 1. Introduction
Tornado research in Europe, including significant climatological studies, has been proactively discussed during the last few decades especially within the series of European Conferences on Severe Storms (ECSS) (Snow and Dessens, 2000). Fundamental to European tornado research was the contribution by the Tornado and Storm Research Organization (TORRO) (Meaden, 1976; Doe, 2016). The European Severe Weather Database (ESWD) was established by the European Severe Storms Laboratory (ESSL) and represents an ongoing effort in European tornado data collection (Groenemeijer and Kühne, 2014).

Tornado occurrence in Greece has seen increased reporting over the last 15-years, preliminarily attributed to the systematic effort for data collection and the development of a reliable and comprehensive database (Sioutas, 2003; Sioutas and Keul, 2007; Sioutas, 2011). Based on this database, the first Greek tornado climatology has been established. This offered useful information to a variety of end users, including weather forecasters, state authorities and services, manufacturers, insurances and the public. This ongoing initiative, incorporating technological advancements such as time-lapse video and smart phone cameras, has resulted in upgrading of observational opportunities and quantitative and qualitative improvement of the database.

The primary objectives of this study are to:

- **enhance** understanding of the spatiotemporal distributions of tornadoes affecting Greece
- **analyze** the 5-year (2010-14) tornado dataset with reference to the 10-year (2000-09) dataset
- **examine** influencing factors such as: a) population density, b) improvements in recording and the proliferation of observers, c) observational technology achievements, d) reporting improvements, e) public awareness of tornadoes.

## 2. A 15-year Greek tornado climatology

### 2.1 Temporal distribution

Summarizing the 15-year data of the Greek tornado database (2000-2014):

- A total of **1112 tornado events** were reported **in 769 days** during the 15-year period 2000–14
- **Tornadoes in 209 days** with **220 events**. *Maximum tornado activity was reported the year 2009 with 23 events*.
- **Waterspouts** in **408 days** with **675 events**. *Maximum waterspout activity was reported the year 2014 with 144 events.*
- **Funnel clouds** in **152 days** with **217 events**. *Maximum funnel activity was reported the year 2014 with 55 events.*
- Late **Autumn** presents the greatest tornado activity, followed by **Winter** and then **Summer**.
- **Seasonality** is indicated in waterspout occurrence with maximum activity in the **September-December** period.

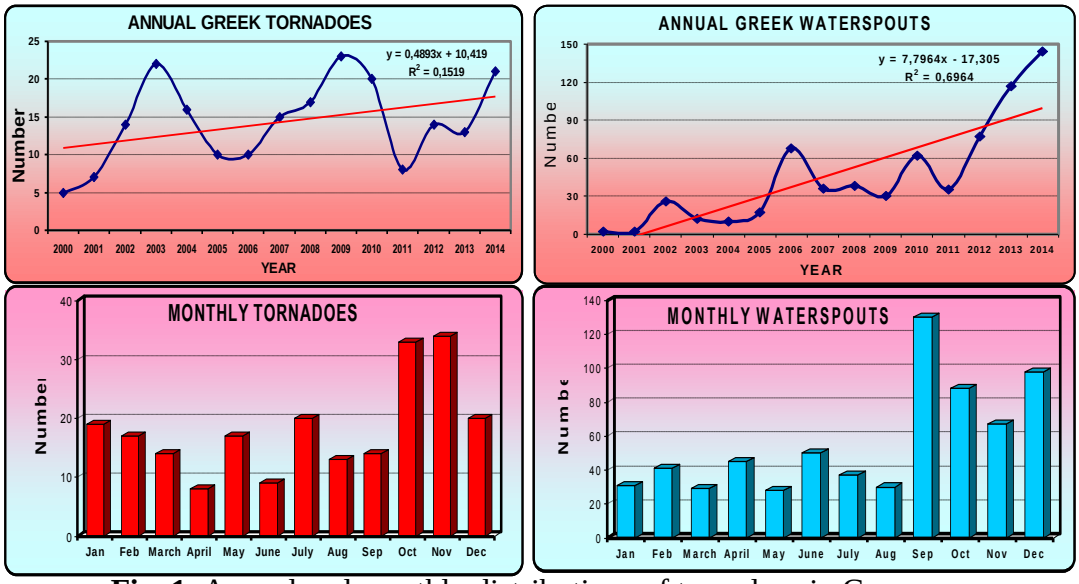


**Fig. 1.** Annual and monthly distributions of tornadoes in Greece.

### 2.2. Spatial distribution

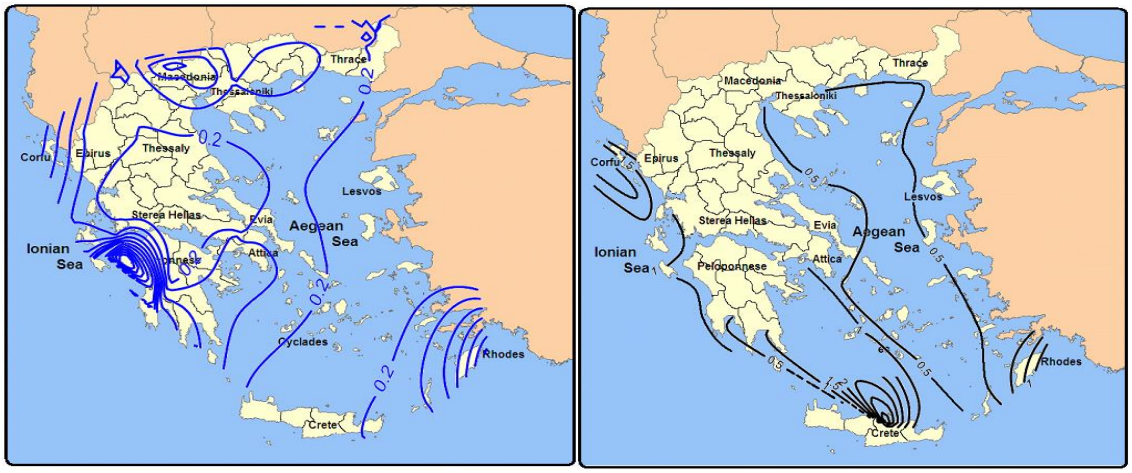


**Fig. 2.** Yearly average days of occurrence for tornadoes (left) and waterspouts (right).

As shown in Figure 2, higher tornado occurrence is determined for western Greece coasts. Waterspout local maximum is located over north off shore of Crete. Tornado local maximum is located over northwest Peloponnese, with a yearly average of 2.5 tornado days. Coastal and low elevation areas generally exhibit increased tornado frequency.

## 3. A 5-year breakdown analysis of the Greek tornado database

Analysis of the 15-year Greek tornado database, in three 5-year datasets, namely the periods 2000-04, 2005-09 and 2010-14, revealed a steady increase in reporting more pronounced in waterspout occurrences (Figures 3 and 4). This increase is most evident in the last 5-year period (2010-14) with more active reporting from volunteers, media, authorities and social media. Technological achievements, including the extensive use of mobile phones, cameras, video and the internet, have significantly increased reporting enabling improvements in both data quantity and quality.

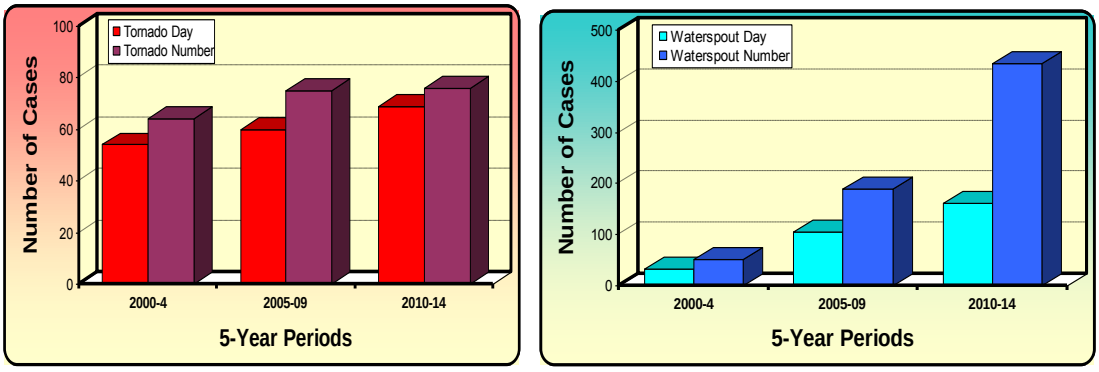


**Fig. 3.** Total tornado (left) and waterspout (right) occurrences for 5-year periods.

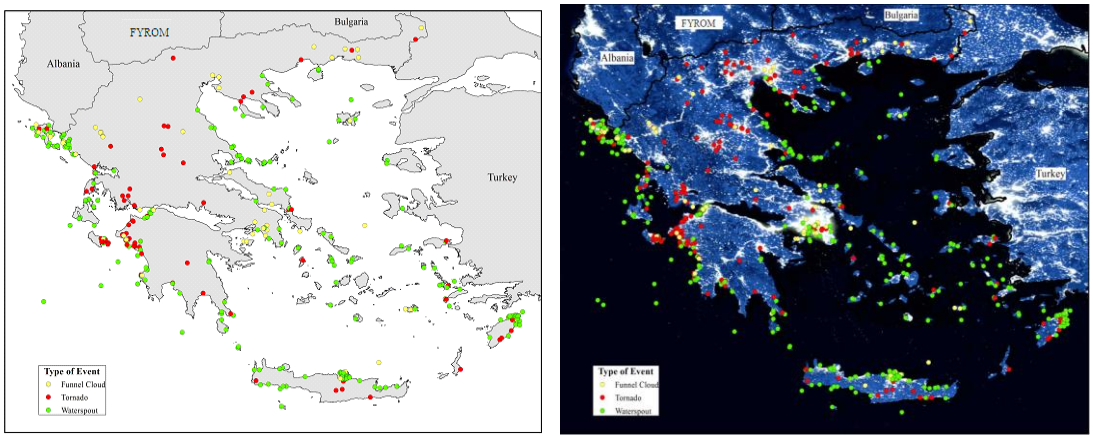


**Fig. 4.** Greece tornado occurrence:5-year (2000-14) (left) and 15-year (2000-14) (right).

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